PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : C11D 1/66, 17/00

A2

(11) International Publication Number: WO 89/11523

(43) International Publication Date: 30 November 1989 (30.11.89)

(21) International Application Number: PCT/GB89/00577

(22) International Filing Date: 25 May 1989 (25.05.89)

(30) Priority data:

224781	25 May 1988 (25.05.88)	NZ
226883	8 November 1988 (08.11.88)	NZ
228153	27 February 1989 (27.02.89)	NZ

(71) Applicants: PIPER, James, William [GB/NZ]; Level 4, Entrance One, 46 Brown Street, Ponsonby, Auckland (NZ). CADAC HOLDINGS LIMITED [NZ/NZ]; Level 4, Broadway Centre, 239 Broadway, Newmarket, Auckland (NZ).

(72) Inventors: CLARK, Peter, Bruce ; Sandspit Road, Sandspit, Warkworth, Auckland (NZ). BOYS, John, Talbot ; 15a Island Bay Road, Birkdale, Auckland (NZ).

(74) Agent: DEARING LAMBERT & CO.; 109 High Street, Ibstock, Leicestershire LE6 1LJ (GB).

(81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, RO, SD, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent).

Published

Without international search report and to be republished upon receipt of that report.

(54) Title: ROTOR POSITION SENSING

(57) Abstract

Electronic rotor position sensing means is disclosed for a multi-phase permanent magnet DC motor (110) having windings (W1, W2, W3) on a substrate (124) of low magnetic permeability. Means for sensing the voltages in the windings are used to switch SCR's "on" at the correct rotor positions to provide electronic commutation. These sense windings may be the same windings as the motor windings (W1, W2, W3) or separate sense windings (W1*, W2*, W3*) which are electrically isolated from but magnetically coupled to the motor windings (W1, W2, W3). In a multi-phase motor the voltage of each phase can be electronically reconstructed by measuring the voltages of the other phases to increase the switching resolution. A resolution of 6 x number of permanent magnetic poles is described.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	ML	Mali
AU	Australia	FR	France	MR	Mauritania
BB	Barbados	GA	Gabon	MW	Malawi
BE	Belgium	GB	United Kingdom	NL	Netherlands
BF	Burkina Fasso	HU	Hungary	NO	Norway
BG	Bulgaria	IT	Italy	RO	Romania
BJ	Benin	JP	Japan	SD	Sudan
BR	Brazil	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic	KR	Republic of Korea	SN	Senegal
CG	Congo	LI	Liechtenstein	SU	Soviet Union
CH	Switzerland	LK	Sri Lanka	TD	Chad
CM	Cameroon	LU	Luxembourg	TG	Togo
DE	Germany, Federal Republic of	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

"ROTOR POSITION SENSING"

This invention relates to position sensing in an electric motor in which the wound poles (or "windings") are supported on a substantially non-conducting substrate of low magnetic permeability (called "a motor of the type described").

An example of such a motor is described in our International patent specification PCT/GB 88/00742. For convenience we will refer to such a motor as one having a substantially "ironless stator" as it is generally convenient to provide the wound poles on the stator rather than on the rotor.

Our earlier patent specification describes a permanent magnet dynamo electric machine which can be provided in the form of a motor/alternator/generator. When provided in the form of a permanent magnet motor, we prefer that it has the permanent magnets on the rotor, and the wound poles on an ironless stator.

It is an object of this invention to provide an improved means for controlling a motor, of the type described, or one which will at least provide the public with a useful choice.

In one aspect, the invention provides control means for a multi-phase electric motor of the type described having a winding associated with each phase of the motor, a unidirectional electronic switching means in series with each winding, the windings being positioned in parallel between a power supply, current blocking means between the power supply and the windings, and means for sensing the voltages in each respective winding, the or each sensing means being connected to means for controlling the respective unidirectional switching means for that winding.

In another aspect the invention provides means for reconstructing the switched phase of a multi-phase machine by comparing the voltages of the other phases.

Preferably the unidirectional switching means consists of silicon controlled rectifiers as they are extremely reliable switching

devices and of very low cost.

As will be described in the preferred embodiment, these silicon controlled rectifiers (SCRs) make use of an effect we call the "phase commutation effect", effect which is possible with a motor of the type described having an ironless stator.

In some cases the sense windings may be the same as the motor windings. Alternatively, the sense windings may be separate windings electrically isolated from the motor windings, and this is preferred in the case of higher voltage motors, or motors having a high starting current.

We have found that the sensing technique described above is particularly suited for the control of motors during running, and is also suitable for high speed motors at start-up. However, for larger slower motors we prefer to include magnetic sensors to sense the position of the rotor at start-up. Such a system may be used during the running of the motor, although we prefer in most cases that the magnetic sensors be used to sense the rotor position during start-up and then prefer to switch over to the electronic sensing technique during high speed running of the motor.

In this aspect, the invention provides means for detecting the position of a permanent magnetic pole in an electric motor, in which a plurality of permanent magnetic poles are provided on a support of a first motor component and one or more magnetic sensors are positioned relative thereto on a second motor component so that the magnetic flux sensors may detect the position of the permanent magnetic poles.

By this means it is possible to make use of the permanent magnetic poles provided on the rotor as part of the sensing arrangement. The magnetic flux sensors may for example be Hall-effect sensors, or magneto-strictive sensors.

In a yet further aspect, the invention provides control means for

a multi-phase electric motor of the type described having both the sensor windings as described above and the magnetic flux sensors as described above.

These and other aspects of this invention, which should be considered in all its novel aspects, will become apparent from the following description, which is given by way of example only, with reference to the accompanying drawings in which:

Figure 1: shows a general circuit diagram for a three phase motor of the type described.

Figure 2: shows the voltage wave forms of the three windings of the motor having an ironless stator.

Figure 3: shows a preferred comparator amplifier on one of the motor windings capable of sensing when the voltage of that winding crosses the zero voltage point. Only one such amplifier is shown, although it will be appreciated that a separate comparator amplifier is provided on each of the windings of Figure 1.

Figure 4: shows the switching points on the wave forms for a three phase supply.

Figure 5: shows a general circuit diagram for a three phase motor of the type described having separate sensor windings as described above.

Figure 6: is a cross section of a motor having a cylindrical rotor with the permanent magnetic poles protruding beyond the end of the rotor.

Figure 7: is a partial end elevation of the rotor of Figure 6 showing the lines of magnetic flux from the protruding portions of the magnetic poles.

Figure 8: illustrates a partial end elevation of the rotor of

Figure 6 showing one possible arrangement of the magnetic flux sensors.

Figure 9: illustrates a part exploded view of an electric motor for use with the control means of this invention.

FIGURE 1:

In the general circuit of Figure 1, it will be appreciated that each winding W1, W2, W3 has its own unidirectional switching means for example SCR1, SCR2, SCR3, each of which is in series with its respective winding. These windings are provided in parallel between a voltage supply V+ and ground. In this example, we are concerned with a three phase motor having an ironless stator, as such a three phase winding motor may use 120 electrical degree current injection. Current controlling means L in the form of an external inductor, or DC-DC series choke converter preferably provides current controlling between the power supply and the electric motor in order to allow the phase commutation to occur. These windings W1, W2, W3, can be used both as "sense windings" and as "motor windings" for a motor of the type illustrated in Figure 9.

The phase commutation effect allows current flowing in winding W1 to stop when winding W2 is switched on. This occurs because when winding W2 is switched on its back EMF voltage is much less than that of winding W1, thus all the current which was previously flowing through winding W1 is transferred into winding W2. When this occurs, the current in winding W1 drops to zero, and when it reaches zero, SCR1 turns off and is therefore commutated. This will be explained in more detail with reference to the phase diagram of Figure 2.

FIGURE 2:

Figure 2 shows the voltage wave forms of the three windings of the motor. Current flows in winding W1 from zero to 120 electrical degrees, and then current flows in winding W2 from

120-240 electrical degrees, and finally current flows in winding W3 from 240-360 electrical degrees.

Phase commutation of winding W1 occurs at 120 electrical degrees when winding W2 is switched on by applying gate drive to SCR2. As the back emf voltage from winding W2 is zero a circulating current through winding W1, and W2 can exist while both SCR_1 and SCR_2 are on together. This current is sourced from the back emf from winding W1 and reduces the current in SCR_1. As soon as the current flowing in winding W1 reaches zero, SCR1 turns off (ie it is commutated). Winding W3 has the same effect on winding W2, ie SCR3 is turned on at 240 electrical degrees and thus SCR2 is commutated. Similarly, winding W1 has the same effect on winding W3, as SCR1 is turned on at 360 electrical degrees and thus SCR3 is commutated. This cycle completes 360 degrees of electrical rotation of the motor.

By sensing the voltages in each of the windings, it is possible to provide a suitable gate signal to turn each of the SCRs on at the correct positions, eg at 0, 120, and 240 electrical degrees.

FIGURE 3:

This is preferably achieved by a comparator amplifier on each winding which senses when each winding's voltage crosses the zero voltage point (as shown in Figure 2). A typical circuit is shown in Figure 3, and for simplicity is shown applied to only one of the windings (although a similar circuit will be provided on each of the windings W1, W2, W3).

In Figure 3, the amplifier A senses when the voltage on winding W1 crosses the zero voltage point (ie at 0 or 360 electrical degrees) and thus provides a gate signal to turn on SCR1. Similarly, the comparator amplifiers for windings W2 and W3 sense when the voltage on winding W2 passes the zero voltage point, ie at 120 electrical degrees, and senses when the voltage on winding W3 passes the zero voltage point, ie at 240 electrical degrees. In this circuit, Resistor R2 = R4; and Resistor R3 = R5.

As the motor is constructed with an ironless stator, the voltage wave forms are substantially sinusoidal without slot ripple, and with minimal voltage variations caused by current flowing through either of the other two windings of the three phase motor. This allows very accurate rotor position sensing and provides a suitable gate signal to switch the SCRs on at the correct points to provide reliable commutation.

It will be appreciated that such a system is applicable to any multi phase motor, although for ease of starting, it is preferred that the motor has three or more phases. The preferred unidirectional switching means is a silicon controlled rectifier, although other possible switching devices may be used. The comparator amplifier shown in Figure 3 is only one of many ways of sensing the crossing point of the voltage in the winding, and many other circuits can be used to monitor this position.

FIGURE 4:

The rotor position sensing technique described above has been further developed and will be explained with reference to a three phase supply with the phases labelled "Red" (R), "Blue" (B), and "Yellow" (Y) in Figure 4.

In essence for a three phase supply, the "Red" phase should be switched at a negative going zero crossing and similarly for the other phases.

Since the act of switching causes a major disturbance, some gating can also be added - for example, after a switching, signals can be ignored (locked out) for say 200 micro-seconds.

With the gating for forward rotation the condition is switch on the "Red" phase, if "Red" phase goes low the "Yellow" phase is high. An alternative condition is "Red" phase goes low, and the "Blue" phase is low, but this technique can actually run backwards with 240° conduction since the "Blue" phase must always

be low if it is switched ON.

When the "Red" (for example) phase is switched ON, the "Red" terminal voltage is determined by the power supply voltage so that the sine wave, as shown in Figure 4, cannot be observed at the Red terminal. However, since the sum of the three terminal voltages must add to zero, the actual "Red" terminal voltage can be reconstructed by taking:

"Red" = 0 - "Yellow" - "Blue"

In this way all three phase voltages can be observed even when the motor is running by reconstructing the switched phase and selecting either the reconstruction or the actual terminal voltage as different phases are switched ON.

Such a technique means that the rotor position can be sensed at all times provided that the rotor is moving and generating terminal voltages. The resolution is then 3 x the number of poles, if all zero crossings are used.

Using this technique allows a new starting method to be introduced. If only the "Red" phase is switched on, the motor will finally come to rest in a position of stable equilibrium, but because of the very low damping factor that it has, this may take a very long time.

With reference to Figure 4 the dots "." represent points of unstable equilibrium so that switching the phases there drives the motor from these points. The crosses "X" represent stable points so that if the "Red" phase is switched ON the motor will finally settle at the stable Red point. Movement in either direction from this point would cause the Red phase voltage to go positive but such a change cannot be seen as the terminal voltage is at the switch potential. The Red phase voltage can however be reconstructed from - (Y + B).

Then, as the motor oscillates about the stable point, the "Red"

voltage will go from -ve to +ve through zero while Blue is +ve. (For -ve rotation "Red" goes +ve while "Yellow" is +ve). At this point the "Yellow" phase can be switched ON and the motor will continue to run with the rotor position sensing described with reference to Figures 1 - 3.

If the motor does not oscillate it must already be at the stable point and the "Yellow" phase can be switched on to effect a start.

This rotor position sensing technique need not be limited to only three phase zero crossings giving 3 x the number of poles. Extra zero crossings can be created - for example (R + Y/2) gives a new waveform.

$$\left(R + \frac{Y}{2}\right) = V\left[\sin wt + \frac{1}{2}\,(wt-120^\circ)\right]$$

$$= V\left[\sin wt - \frac{1}{4}\sin wt - \frac{\sqrt{3}}{4}\cos wt\right]$$

$$= \frac{\sqrt{3}V}{2}\left[\frac{\sqrt{3}}{2}\sin wt - \frac{1}{2}\cos wt\right]$$

$$= \frac{\sqrt{3}V}{2}\sin(wt - 30^\circ)$$

Thus this waveform has zero crossings displaced 30° from the parent waveforms. The same process can be repeated for the other phases to give 6 more zero crossings/cycle or a resolution of 6 x the number of poles.

Other combinations can also be added to increase the resolution yet further, if required, but there is a practical limit dependent on the degree of distortion in the waveforms.

It will be appreciated that the phase commutation effect provides a simple and reliable means of controlling the direct current motor as described in our earlier patent specification and is also applicable to any other type of permanent magnetic motor in which the wound poles are provided on a substrate of low magnetic

permeability. Although this effect is particularly suited to our earlier motor, it is applicable also to the "pancake motor" in which the permanent magnets are mounted on a flat disc adjacent another disc on which the wound poles are provided. Thus the control means of this invention are applicable to any form of motor having an ironless stator (ie having wound poles on a substrate of low magnetic permeability) as this minimises voltage variations caused by the current flowing through the other windings.

FIGURE 5: Separate Sense Windings

In the general circuit for Figure 5, it should be noted that each of the windings W1, W2, W3... supplying power to the motor is wound together with a separate, electrically isolated winding W1*, W2*, W3*... magnetically coupled so as to sense rotor position by means of the back-emf voltage generated within the corresponding power winding during action of the motor. These sense windings are connected with correct polarity to the inputs of an electronic device (10) which constructs the proper control signals to the stator current-switching devices (11,12,13) on the basis of external commands plus information from the sense windings. By way of example the current-switching devices shown in Figure 5 are transistors.

An advantage of this invention is that the signals available from the sense windings are less distorted than signals from the power windings; an important advantage if the motor is to be started with high currents.

Another advantage of this invention is that the option of a high-voltage motor supply can be selected without consideration for the rotational sensing system because the voltages available from the separate sense windings remain compatible with the electronic circuitry.

A further advantage is that, in contrast to our earlier schemes involving direct sensing of voltages from the motor's supply

windings, accurately divided signal voltages which were especially necessary at startup and required precision resistors or careful adjustments are no longer needed because the input voltages from the sense coils are now compared with zero volts instead of a fraction of the voltage across both the motor and its current-switching devices.

FIGURE 6: <u>The Magnetic Position Sensor</u>

Figure 6 shows one example of the use of magnetic position sensors to determine the position of the magnetic poles irrespective of motion. Transducers (21) of a steady magnetic flux passing through a small volume are required and by way of example are shown as the solid-state Hall-effect devices. The type of motor used by way of example carries on its rotor (22) an alternating series of longitudinal north and south poles (23) and uses the inner series of poles, interacting with the magnetic fields of the energised stator coils, to generate motion.

Here, the outer series of poles incidentally present though preferably constructed to protrude beyond the structure of the rotor (22) are made to interact with the fixed set of magnetic position sensors (21) (and 41, 42, 43 in Figure 8) to provide information concerning the relative position of the sensors and the array of magnetic poles. A convenient extent of protrusion is 5 mm.

The general practice in the application of Hall-effect or similar sensors is to place them at the end, or within the rotors of outside-rotor electric motors. In our invention the flux transducers are preferably placed on the outside.

One advantage of this placement of the magnetic flux sensors is that they are screened from the flux generated by currents in the stator windings. Such interference would alter the accuracy of determining switching points and lower the efficiency of the motor.

Furthermore, it is preferable to mount them outside the circumference of the rotor, because the volume within it is consumed by the flat stator winding (not shown).

The array of magnetic position sensors is then coupled to the electronic controller described with reference to Figure 5, using the appropriate interfacing and signal conditioning elements.

FIGURE 7: <u>Flux Diagram for the Magnetic Position Sensor</u>

Figure 7 is a partial end elevation of the series of magnetic poles (31, 32, and 33) which by way of example are mounted along the edge of the rotor of a simple motor. The flux lines, or lines of magnetic force are shown. It will be appreciated that the amount of flux is considerably larger if the poles project beyond the confines of the iron rotor frame.

FIGURE 8: <u>The Magnetic Position Sensor</u>

Figure 8 is a partial end elevation of the series of magnetic poles which by way of example are mounted along the edge of the rotor of a simple motor. One preferable arrangement for the mounting of the magnetic flux sensors (41, 42, and 43) is shown in which physical separation around the circumference of the rotor in relation to the spacing of the magnetic poles may indicate the present position of the rotor and be used as a source of signals with which to control the starting and running of the motor. The indicated spacing in degrees refers to the electrical phasing of the sensors with reference to a three-phase system using three sets of stator coils.

FIGURE 9: <u>External Rotor Motor</u>

In this example, a co-axial motor is illustrated, having an external rotor construction utilizing closely spaced straight bar magnets, and a substantially "ironless stator".

The motor 110 has a cylindrical sleeve 111 which is conveniently

in the form of a cup having an end face 112, which is attached to a central shaft 113. This shaft is preferably mounted within bearings 115 mounted within a stator 116. Conveniently, the shaft has a tapped end 117 for connection to other machinery.

The inner face of the sleeve 111 is provided with a plurality of side by side bar magnets 127, aligned with their axes parallel to the axis of the rotor and with their ends preferably protruding slightly beyond the end of the sleeve 11. It will be appreciated that there will be an even number of such closely spaced magnets, so that the polarity of the permanent magnetic poles alternates as one travels around the inner circumference presented by these magnets.

The magnets are preferably rare earth or ceramic bar magnets, and 20 such magnets are shown in Figure 9, for the purpose of illustration. Any even number of such magnets can be used depending upon design criteria such as size, weight, price, availability and frequency.

Preferably the bar magnets are formed from either rare earth or ceramic magnets, and have a high field strength enabling them to provide a higher magnetic flux across a much wider air gap than is possible with conventional magnets, but at the same time it is preferred that the adjacent permanent magnetic poles are close together to provide a short magnetic flux path between adjacent magnetic poles.

Preferably, the rotor sleeve and end face, are formed of steel although other materials could be used.

The stator 116 is preferably connected to a mounting plate (not shown), which may also support magnetic flux sensors as shown in Figure 8, if magnetic sensors are also used to detect the position of the magnets.

It is preferred that the rotor and stator are spaced apart by a relatively large cylindrical air gap of the order of 0.25mm to

1.5mm and preferably 0.75mm for the 20 pole motor/alternator of this example. This enables the wound poles to intersect the magnetic flux path as at substantially right angles thereto. The air gap is preferably less than the depth of the magnets and should be of such a size as to allow for normal engineering clearances and tolerances.

The stator has an annular generally cylindrical substrate 124 of low magnetic permeability material with a plurality of wound poles or windings 125 on its outer cylindrical surface. A preferred substance is glass reinforced plastics resin as this can be formed into a sufficiently rigid cylindrical surface which on a prototype machine without a fan has not distorted in use. The number of wound poles correspond to the number of permanent magnetic poles inside the rotor. The wound poles are relatively shallow in that they are formed on or close to the surface of the substrate (unlike conventional wound poles which are wound within slots formed in steel laminations). The depth of the wound poles on or close to the surface of the stator will depend upon the size of the stator and required rating of the motor. In the example shown, the depth would be of the order of 1mm to 10mm, and preferably about 3mm.

It will be generally convenient to provide the wound poles or windings as wave windings on that surface of the stator facing the permanent magnetic poles. For example *Figure 9* shows the wave windings W1, W2, W3 each providing a plurality of wound poles on the surface of a substrate 124 for a three phase stator winding. A three phase winding is preferred for most applications but other phases have their uses for particular applications. They may be exposed to the air or encapsulated in a plastic resin of low magnetic permeability. Each winding W1, W2, W3 may provide both the sense windings and the motor windings as shown in Figure 1, or separate sense windings W1*, W2*, W3* may be superimposed over but electrically insulated from motor their respective windings as described with reference to Figure 5.

The wound poles may be provided in a variety of forms and may

provide for one or more phases. As the substrate is of low magnetic permeability there is consequently no iron (at least in the outer portion of the substrate) to provide a magnet flux path in the stator. The wound poles on the surface of the stator are so positioned as to intersect the magnetic flux lines connecting adjacent ceramic magnets as the flux lines essentially form a series of loops from one magnet to the next as one travels around the inner circumference of the rotor.

VARIATIONS:

While the specification above generally refers to a three-phase rotational motor, the principles of the invention are generally applicable to motors with other numbers of phases and to "pancake" or radial electric motors as well as cylindrical motors having internal or external rotors.

Finally, various other alterations and modifications may be made to the foregoing without departing from the scope of this invention as exemplified by the following claims.

CLAIMS:

1. Control means for a multi-phase electric motor (110) in which motor windings (W1, W2, W3) are supported on a substantially non-conducting substrate (124) of low magnetic permeability, there being a winding (W1, W2, W3) associated with each phase of the motor, CHARACTERISED IN THAT a unidirectional electronic switching means (111, 112, 113) is provided in series with each winding, the windings (W1, W2, W3) are positioned in parallel across a power supply, current blocking means (L) is provided between the power supply and the windings, and sensing means is provided for sensing the voltages in each respective winding, the or each sensing means being connected to means for controlling the respective unidirectional switching means for that winding.

2. Control means as claimed in claim 1, CHARACTERISED IN THAT there is means (10) for reconstructing the switched phase of a multi-phase machine by comparing the voltages of the other phases.

3. Control means as claimed in any preceding claim CHARACTERISED IN THAT the unidirectional switching means (11, 12, 13) consists of silicon controlled rectifiers (SCR1, SCR2, SCR3).

4. Control means as claimed in any preceding claim CHARACTERISED IN THAT the at least one winding associated with each phase of the motor includes a sense winding (W1*, W2*, W3*) and a motor winding (W1, W2, W3).

5. Control means as claimed in claim 4 CHARACTERISED IN THAT each sense winding is electrically isolated from its respective motor winding.

6. Control means as claimed in any preceding claim CHARACTERISED IN THAT there is additional means (41, 42,

43) for detecting the position of a permanent magnetic pole (31, 32, 33) in an electric motor, in which a plurality of permanent magnetic poles are provided on a support of a first motor component and one or more magnetic sensors (41, 42, 43) are positioned relative thereto on a second motor component so that the magnetic sensors may detect the position of a permanent magnetic pole.

7. Control means as claimed in the preceding claim, CHARACTERISED IN THAT the permanent magnetic poles (127) protrude beyond the end of the rotor support (111).

FIG.1

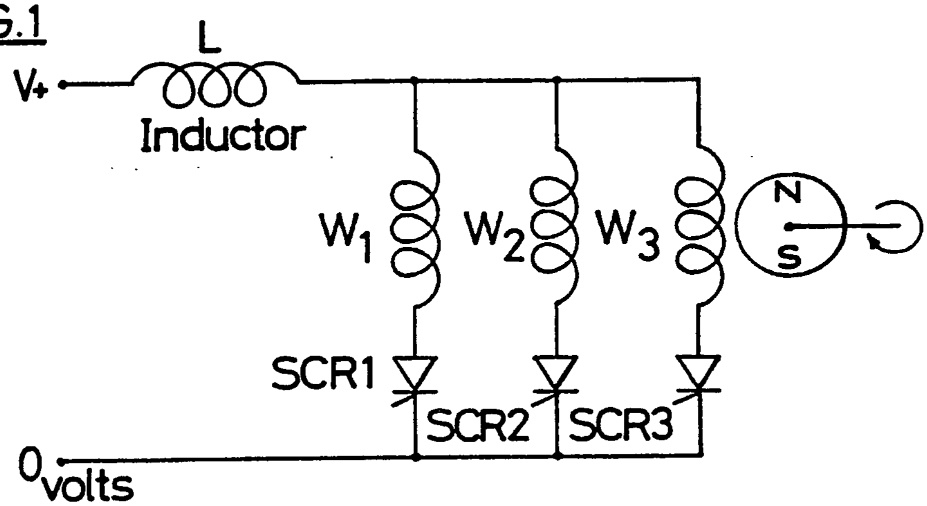


FIG. 2

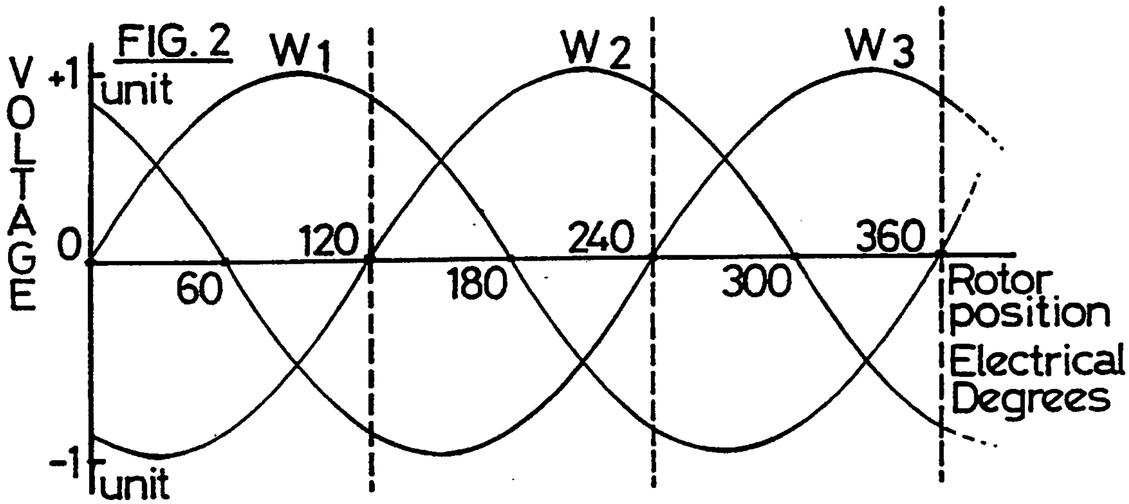


FIG.3

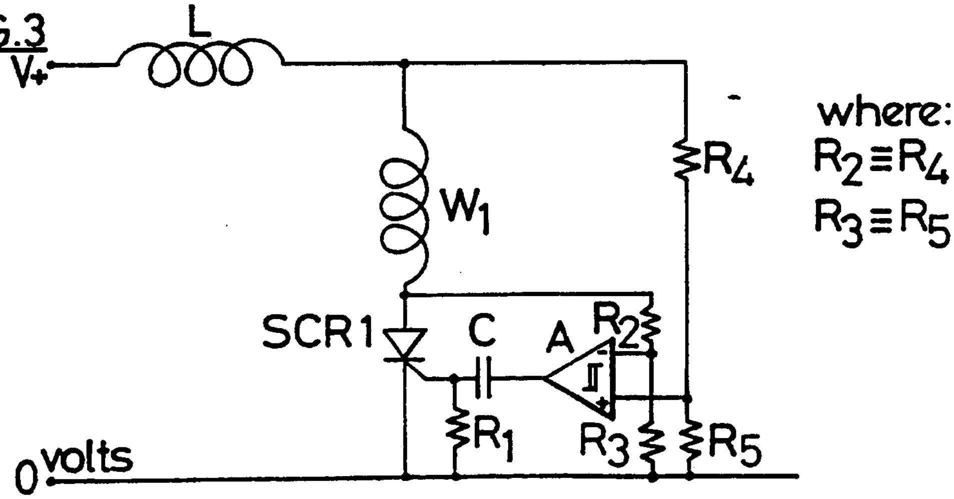


FIG.4

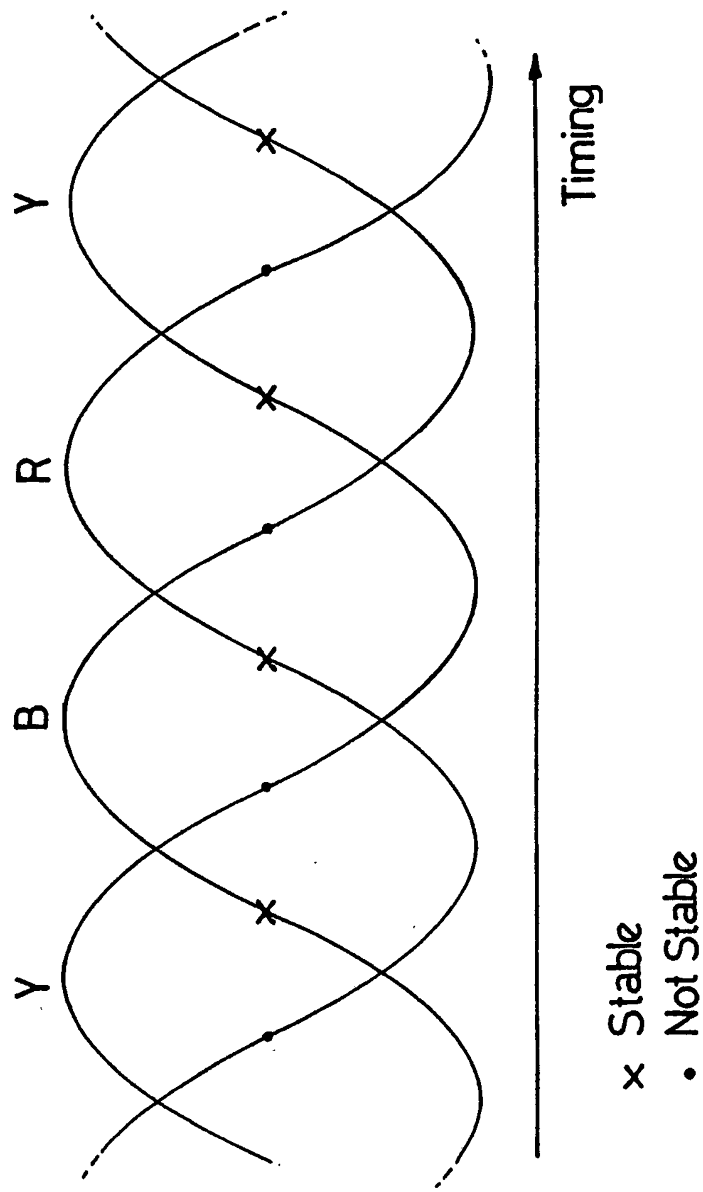


FIG.5

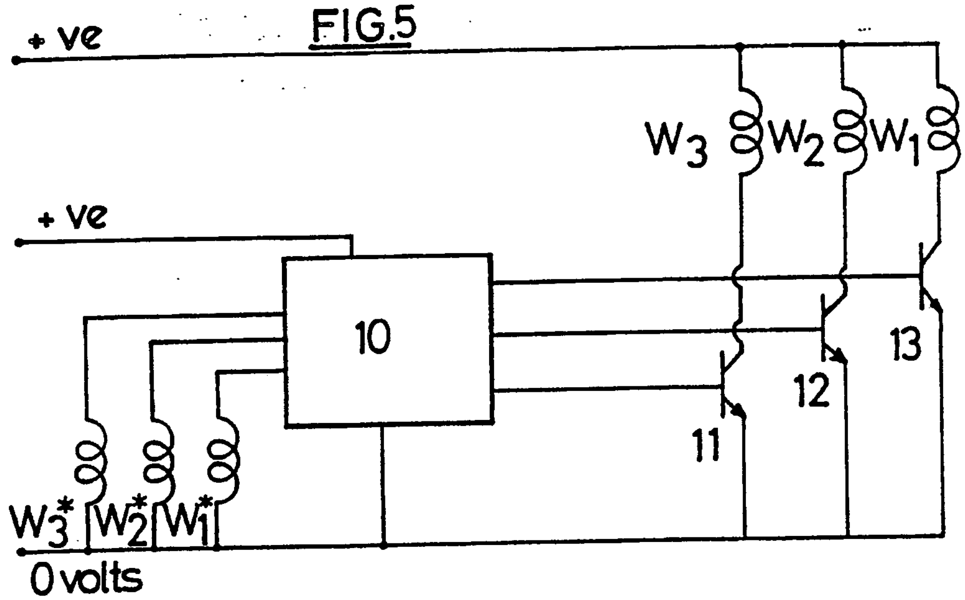


FIG.6

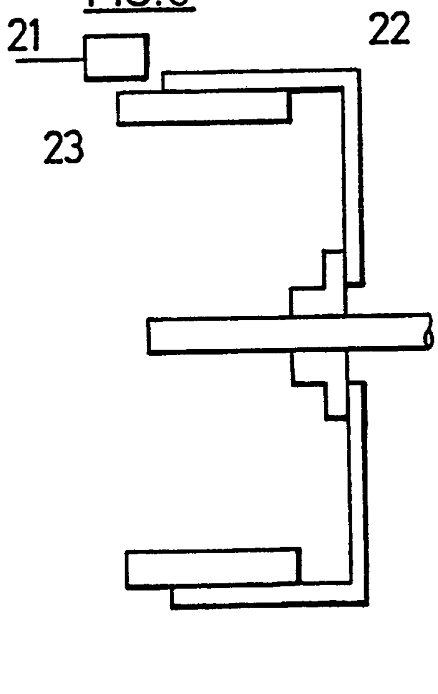


FIG.7

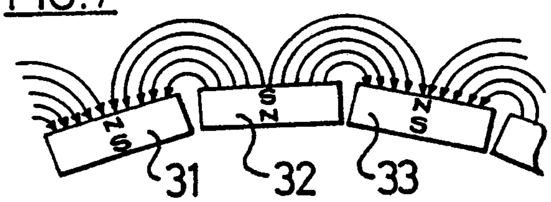
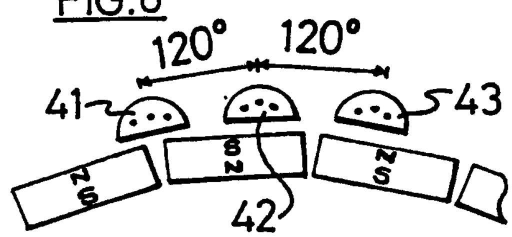


FIG.8



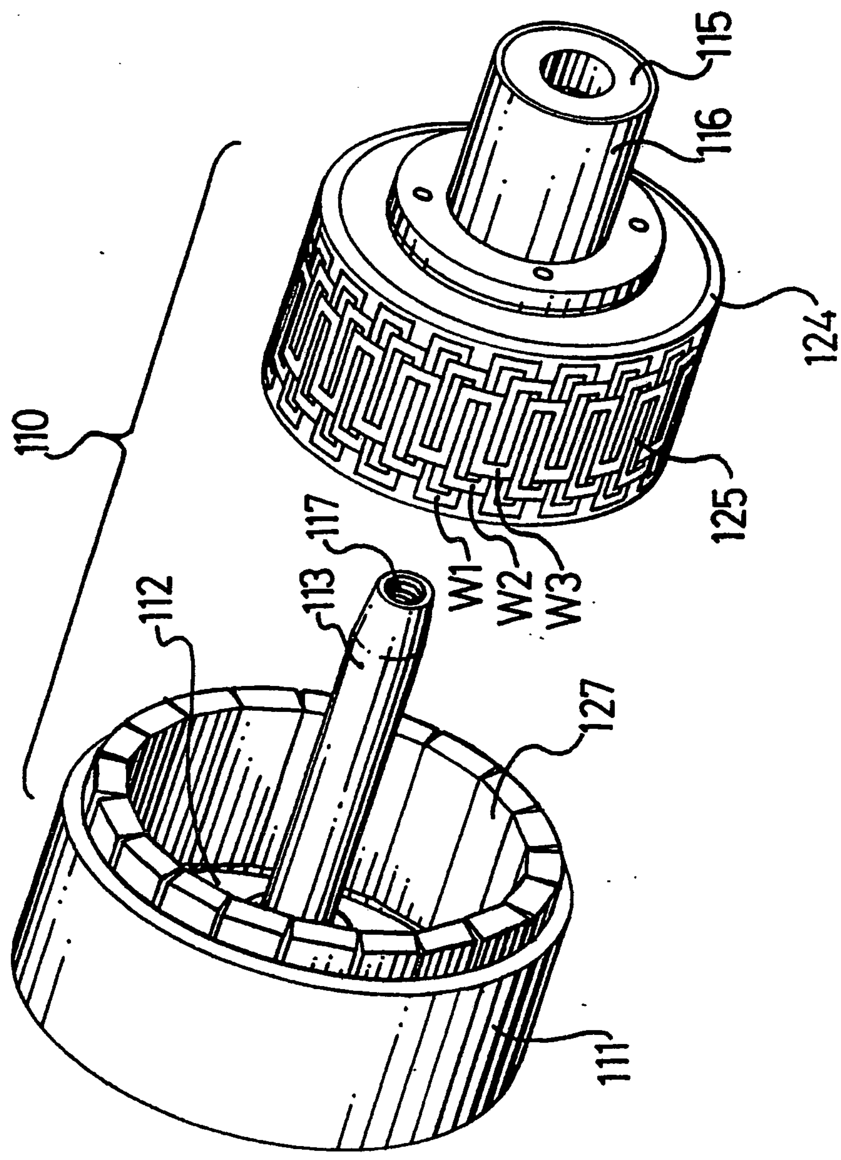


FIG. 9

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : H02P 6/02 | A3

(11) International Publication Number: WO 89/11523

(43) International Publication Date: 30 November 1989 (30.11.89)

(21) International Application Number: PCT/GB89/00577

(22) International Filing Date: 25 May 1989 (25.05.89)

(30) Priority data:

224781	25 May 1988 (25.05.88)	NZ
226883	8 November 1988 (08.11.88)	NZ
228153	27 February 1989 (27.02.89)	NZ

(71) Applicants: PIPER, James, William [GB/NZ]; Level 4, Entrance One, 46 Brown Street, Ponsonby, Auckland (NZ). CADAC HOLDINGS LIMITED [NZ/NZ]; Level 4, Broadway Centre, 239 Broadway, Newmarket, Auckland (NZ).

(72) Inventors: CLARK, Peter, Bruce ; Sandspit Road, Sandspit, Warkworth, Auckland (NZ). BOYS, John, Talbot ; 15a Island Bay Road, Birkdale, Auckland (NZ).

(74) Agent: DEARING LAMBERT & CO.; 109 High Street, Ibstock, Leicestershire LE6 1LJ (GB).

(81) Designated States: AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CF (OAPI patent), CG (OAPI patent), CH (European patent), CM (OAPI patent), DE (European patent), DK, FI, FR (European patent), GA (OAPI patent), GB (European patent), HU, IT (European patent), JP, KP, KR, LK, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL (European patent), NO, RO, SD, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(88) Date of publication of the international search report: 28 December 1989 (28.12.89)

(54) Title: ROTOR POSITION SENSING

(57) Abstract

Electronic rotor position sensing means is disclosed for a multi-phase permanent magnet DC motor (110) having windings (W1, W2, W3) on a substrate (124) of low magnetic permeability. Means for sensing the voltages in the windings are used to switch SCR's "on" at the correct rotor positions to provide electronic commutation. These sense windings may be the same windings as the motor windings (W1, W2, W3) or separate sense windings (W1*, W2*, W3*) which are electrically isolated from but magnetically coupled to the motor windings (W1, W2, W3). In a multi-phase motor the voltage of each phase can be electronically reconstructed by measuring the voltages of the other phases to increase the switching resolution. A resolution of 6 x number of permanent magnetic poles is described.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	ML	Mali
AU	Australia	FR	France	MR	Mauritania
BB	Barbados	GA	Gabon	MW	Malawi
BE	Belgium	GB	United Kingdom	NL	Netherlands
BF	Burkina Fasso	HU	Hungary	NO	Norway
BG	Bulgaria	IT	Italy	RO	Romania
BJ	Benin	JP	Japan	SD	Sudan
BR	Brazil	KP	Democratic People's Republic of Korea	SE	Sweden
CF	Central African Republic	KR	Republic of Korea	SN	Senegal
CG	Congo	LI	Liechtenstein	SU	Soviet Union
CH	Switzerland	LK	Sri Lanka	TD	Chad
CM	Cameroon	LU	Luxembourg	TG	Togo
DE	Germany, Federal Republic of	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

INTERNATIONAL SEARCH REPORT

International Application No. PCT/GB 89/00577

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 4 H02P6/02

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 4	H02P

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
Y A	FR,A,2267650 (TELDIX GMBH) 07 November 1975 see page 9, lines 3 - 24; figure 1 ---	1 2, 4, 5
Y	US,A,4051417 (M. FUJINAWA ET AL) 27 September 1977 see figures 1, 6 ---	1
A	FR,A,2577355 (ROTRON INC.) 14 August 1986 see the whole document ---	1, 6
A	PATENT ABSTRACTS OF JAPAN vol. 7, no. 45 (E-160)(1190) 23 February 1983, & JP-A-57 196893 (TOKYO SHIBAURA DENKI K.K.) 02 December 1982, see the whole document ---	1, 3
A	EP,A,231046 (PHILIPS PATENTVERWALTUNG GMBH) 05 August 1987 ---	

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
08 NOVEMBER 1989	30. 11. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	BEYER F.

1

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

PCT/GB 89/00577
SA 29178

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 08/11/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-2267650	07-11-75	DE-A,C	2417818	23-10-75
		DE-A-	2511567	30-09-76
		CH-A-	590581	15-08-77
		GB-A-	1500955	15-02-78
		JP-A-	50144018	19-11-75
		US-A-	3974406	10-08-76
US-A-4051417	27-09-77	JP-A-	51028610	11-03-76
		DE-A-	2538835	18-03-76
		GB-A-	1515186	21-06-78
FR-A-2577355	14-08-86	US-A-	4618806	21-10-86
		DE-A-	3602138	14-08-86
		JP-A-	61189162	22-08-86
EP-A-231046	05-08-87	DE-A-	3602227	30-07-87
		JP-A-	62173999	30-07-87
		US-A-	4752724	21-06-88

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82